POTENTIAL FOR DEVELOPMENT OF A NORTHERN CALIFORNIA FISHERY FOR PACIFIC HAKE

By Raymond Swanson and Richard L. Ridenhour

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By

Raymond Swanson[2/]

and

Richard L. Ridenhour

Humboldt State University

Arcata, California 95521

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[2/]Present address: Tom Lazio Fish Company, Inc., Eureka, California

INTRODUCTION

The potential of Pacific hake (Merluccius productus) as a commercially usable species has been the subject of discussions by fishermen and fish processors for a number of years. In northern California, the interest has been prompted mainly by trawl fishermen who have caught large amounts of hake while fishing for other species. The National Marine Fisheries Service has been studying Pacific hake since the early 1960's and has published information on various aspects of the commercial development and management of this resource (U.S. Fish & Wildlife Service, 1970). Also, since 1966, a substantial foreign fishery for Pacific hake has been developed. In about 1975, it became apparent that the United States would probably adopt legislation declaring control of fishing activities within 322 km. (200 miles) of the U.S. coast. These various factors led fishing industry representatives in northern California to urge that a project be initiated by the Sea Grant Program at Humboldt State University to investigate the feasibility of, and procedures for, establishing a hake fishery. A project intended to compile available information on hake and to process a sufficient quantity of hake in order to evaluate product acceptability and salability for human consumption was begun in 1976.

THE PACIFIC HAKE RESOURCE

Pacific hake occur along the Pacific Coast of North America from the Gulf of Alaska to the Gulf of California (Alverson, Pruter, and Ronholt, 1964). Adult hake are largely concentrated on or near the continental shelf (Best, 1963). There is evidence of a coastwise migration northward during the spring and summer and southward in the fall (Nelson and Larkins, 1970).

Hake apparently spawn once each year (MacGregor, 1966), from December to April, in areas off southern California and Baja California as far offshore as about 485 km. (300 miles) (Ahlstrom and Counts, 1955). The pelagic eggs drift with ocean currents and hatch in about three days (Nelson and Larkins, 1970). The larvae continue to drift for a few more days before beginning a northward migration. Juvenile hake, ages 1 to 3 and from 11.75 cm. to 34.5 cm. (4.7 inches to 13.8 inches) long, are found as far north as northern California and southern Oregon (Best, 1963). Pacific hake live for at least 13 years and reach a maximum total length of at least 78.75 cm. (31.5 inches) (Best, 1963). The foreign fishery at first caught mainly 4-year-old and older fish; but in recent years, it has become increasingly dependent on juvenile (2 - 3 years old) hake (Dark and Nelson, 1977).

Hake are semipelagic, similar to cod, haddock, and various species of rockfish (Saetersdal, 1967). Adult hake

located over the continental shelf are found in long, dense, relatively narrow but discontinuous bands, oriented parallel to the isobaths. Hake found near the edge of the continental shelf and over the continental slope exhibit more variation in their schooling behavior and show no particular orientation with isobath contours. In fact, schools of hake found on the continental slope tend to be located at a constant depth but at right angles to the slope. The schools of hake normally rise at night and become somewhat dispersed, causing catches by midwater trawl to become poorer (Nelson and Larkins, 1970).

The size of the Pacific hake population has recently been estimated to be about 400,000 t. (metric tons) (440,000 tons) (Dark and Nelson, 1977). Based on this population estimate, a total catch of 150,000 t. (165,000 tons) was recommended for 1977, although a maximum sustained yield between 150,000 t. (165,000 tons) and 270,000 t. (297,000 tons) had previously been estimated (Dark and Nelson, 1977).

PACIFIC HAKE FISHERIES

Before 1960, most of the Pacific hake catch was incidental to the catch of other fish. Generally, the hake that were caught were used for animal feed. Vessels fishing under the flag of the Soviet Union entered the fishery in 1966. Since the early 1970's, various other countries

including Poland, the Democratic Republic of Germany (East Germany), the Federal Republic of Germany (West Germany), and Bulgaria have entered the fishery (Dark and Nelson, 1977).

The National Marine Fisheries Service (then the Bureau of Commercial Fisheries) conducted exploratory fishing expeditions for hake off the Oregon and Washington coasts in 1964 (McNeely, Johnson, and Gill, 1965). Catches of as much as 27,250 kg. (60,000 lbs.) per half hour tow and consistent catches of 6,800 kg. (15,000 lbs.) per hour indicated the availability of a resource that might be harvested economically (Nelson, 1970).

During the summers of 1966 and 1967, three U.S. vessels fished for hake off the Oregon and Washington coasts. The National Marine Fisheries Service and the Economic Development Administration provided some assistance to these fishing efforts. The 1967 program was specifically intended to evaluate the potential for producing fish protein concentrate from hake. These efforts resulted in 1,450 t. (1,600 tons) of hake landed in 1966, and 7,950 t. (8,750 tons) in 1967. Even though the resource was available and could be caught by U.S. fishing vessels, these efforts to establish a commercial fishery for hake were considered unsuccessful because the prices paid for the hake were insufficient to induce fishermen to enter and stay in the fishery (Nelson and Dyer, 1970).

PACIFIC HAKE FISHING METHODS

Hake have been caught incidentally by U.S. fishermen using otter and other types of bottom trawls. The exploratory fishing conducted by the National Marine Fisheries Service in 1964, included experimentation with pelagic or midwater trawls (McNeely, Johnson, and Gill, 1965). The Russian fishing, which started in 1966, has used midwater trawls and electronic detection equipment.

The fishing methods used by the Russians have become sufficiently refined and efficient to warrant a more detailed description (see Hitz, 1970). A typical fishing fleet includes side trawlers, stern trawlers, and support vessels. The trawlers range in length from about 37 to 82 meters (125 to 270 feet) and have the capability of catching, processing, and freezing the fish products. The support vessels provide logistical assistance to the trawlers. The fishing operations of the fleet are directed from a command ship which analyzes oceanographic and catch data from the various vessels in the fleet and directs all fishing activities. Electronic equipment is used to locate and identify concentrations of hake, and large midwater trawls are set to catch the fish that have been located. These techniques can be highly selective and efficient (Quirollo[1], personal

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[1]Larry Quirollo, California Department of Fish and Game, Marine Resources Laboratory, Eureka, California.

communication). The fish are processed as soon as they are brought aboard - most for human consumption, although some portions are processed for animal feed and fertilizer. The fish, after they are filleted or headed and gutted, are stored frozen. There is no evidence that the Russians are deboning and making fish flesh blocks while at sea.

HAKE PRODUCT DEVELOPMENT STUDY METHODS

The hake project conducted by the Humboldt State University Sea Grant Program, other than compiling available information, concentrated on the processing and marketing aspects of developing a hake fishery. Previous work done by other agencies and companies and observations of the foreign fishery had established that a substantial hake resource was available and had identified basic methods of harvesting.

Trawling vessels operating out of Eureka cooperated with the investigators by landing hake they had caught in their last tows before returning to port. Two to four hours after being caught, the hake were delivered, un-iced, to the processing plant facilities where they were weighed and iced. A random sample was measured to determine the average length of the catch.

The iced fish were processed into two types of products: headed and gutted fish and fillets. The headed and gutted

fish were re-iced in lots of about 450 kilos (1,000 lbs.) for late processing using a Yanagiya minimodel deboning machine (fish flesh separator) to produce a minced flesh block. The boxes were frozen for about 12 hours in a plate freezer at -23° to -29° C (-10° to -20° F) two to four hours after being deboned. After the initial freezing, they were held in a storage freezer at -18° C (0° F) until they were distributed. Filleting was done by experienced filleters. The fillets were also re-iced until they could be packed into 4.5 kilos (10 lbs.) layer-pack boxes. The packed fillets were frozen in a blast freezer at -32° C (-26° F) for 24 hours and then stored at -18° C (0° F) for later distribution.

After storage for various amounts of time up to several months, samples of the frozen hake were sent to the National Marine Fisheries Service, Home Economics Division, Terminal Island, California, for analyses of product quality and acceptability. Other samples were thawed overnight and cooked for local evaluation. Some samples were packed in dry ice and distributed to potential buyers in the San Francisco and Los Angeles, California, areas for their evaluation.

RESULTS OF HAKE PRODUCT DEVELOPMENT INVESTIGATIONS

Landings

Fishermen landed 2,270 kg. (5,000 lbs.) of Pacific hake for use in this study. Landings were made from June through

October, 1976. The fish averaged from 47.5 to 62.5 cm. (19 to 25 inches) in length and 0.9 to 1.2 kg. (2 to 2.5 lbs.) in weight.

Processing

Filleters found hake to be somewhat soft but not difficult to handle. They felt that filleting hake was comparable to filleting black cod (sablefish). Fillet yields ranged between 26 to 31 percent of the round weight of the fish.

Deboning machinery used to make minced flesh has been available for a number of years. Tests, in which various kinds of seafood were processed with most brands of deboning machines, have been conducted to judge applicability of the machines for use in the fish processing industry (National Fisheries Institute, 1974). Deboning machines with the following characteristics are available:

1. basic design: drum slots and holes from 2 to 10 mm.
2. yields: 18 to 75 percent, depending on the product, species, pressure adjustments, and desired product quality.
3. space requirements: from 1.2 X 1.2 m (4 X 4 ft.) to 7.6 X 7.6 m (25 X 25 ft.).
4. power requirements: 110 V or 220 V.
5. output: 180 to 6,800 kg. (400 to 15,000 lbs.) per hour.
6. operators: one to four.

These machines may be operated on-board ship or in a land-based processing plant. Recent developments have included new head designs, fewer parts, added safety features, and improved serviceability. Tests have been made with deboning machines for processing the following species: cod, whiting, hake, flounder, halibut, mullet, croaker, perch, salmon, pike, carp, shrimp, crab, and lobster. The Yanagiya minimodel used in this study was not designed to process large volumes and was inefficient when processing even a few hundred kilos. In addition, the following problems were encountered:

1. Skin stuck to and wrapped around the drum, allowing skin pigments to pass through and mix with the minced flesh unless the skin was frequently removed from the drum by hand.
2. Skin and bone waste piled up at the ejection point, requiring that the machine be stopped and the waste removed by hand.
3. The machine could not be adjusted precisely enough to ensure a product without flesh color inconsistencies and contamination with particles of skin.
4. White particles, apparently from connective tissue found along the backbone or from small pieces of backbone, were evident in the minced flesh. The amount of contamination was reduced by removing the backbone of the fish before processing.

Yields from headed and gutted fish processed with the Yanagiya deboning machine ranged from 28 to 34 percent of round weight.

Product Quality

The color of the hake flesh varies from an off-gray white to pink, which is within the normal range of color found in various Pacific Coast species of fish that are now filleted and marketed in the seafood industry (Dassow, Patashnik, and Koury, 1970). Fresh raw hake flesh has a neutral odor, but the skin of whole hake develops a strong persistent odor in less than one day if the fish are not iced. They must be iced or stored in chilled seawater or brine immediately aboard the vessel to avoid these strong odors. Fresh hake, or hake that has been properly stored, has a mild flavor when cooked. This mild flavor permits modifications with small amounts of additivies, such as bread and batter or sauce. The result is a flavor that consumers consider desirable. The normal texture of hake flesh is moist and tender but not mushy. Most testers find it quite similar in texture to that of Dover sole and English sole (Dassow, Patashnik, and Koury, 1970).

As indicated, the fish used in this study were off-loaded two to four hours after being caught, iced immediately, and frozen immediately after processing. In spite of being frozen at subzero temperature and stored at 0° C (-18° F),

the quality of the fish for human use deteriorated within a few weeks, mainly due to rancidity of fatty tissues.

During the summer of 1976, samples of frozen fillets which had been stored for one month were evaluated at the National Marine Fisheries Service Pacific Utilization Research Center in Seattle, Washington. The fish were packed in dry ice for shipping. At the Seattle laboratory, the frozen fillets were allowed to thaw overnight in a coldroom and then at room temperature until they could be separated while still soft frozen. The frozen fillets were baked for 20 minutes at 175° C (350° F) and then evaluated for flavor and texture. The fatty portions of some fillets were found to be rancid. Texture ratings for 189 fillets, using a 5-point rating scale, yielded the following results:

1. Very firm, 1 fillet (0.5%).
2. Firm, 47 fillets (24.9%).
3. Slightly soft, 62 fillets (32.8%).
4. Marginally soft, 44 fillets (23.3%).
5. Unacceptably mushy, 35 fillets (18.5%).

The laboratory concurrently tested hake caught off Washington and British Columbia. One sample was filleted and frozen aboard the vessel within four hours of landing, and the other sample was iced for one to three days before being processed. Both samples were steamed for 20 minutes at 100° C (212° F). Fish that had been filleted and frozen

soon after being caught yielded fillets that were less soft and mushy than those that had been iced for one to three days before being filleted (Patashnik, 1976). Similar findings were reported early in 1977 (Pacific Utilization Laboratory, 1977). Frozen hake fillets were provided by a foreign processing vessel. The soft, mushy texture was observed in 40 percent of the fillets, indicating the texture problem is widespread in Pacific hake.

The National Marine Fisheries Service, Home Economics Division, Terminal Island, California, evaluated both fillets and deboned fish. Their taste panel consisted of NMFS employees whose evaluation considered flavor, texture, and overall acceptability. On a scale of 1 to 10, they rated both the fillets and the deboned fish as very good with scores of 8.58 and 8.30 respectively.

Hake fillet samples were delivered to the Crystal Springs Rehabilitation Center in San Francisco. The Center's dietician reported the fish had a bland flavor but made no comment regarding texture.

Hake products were tried by about 50 local individuals. Each person was interviewed informally and asked to comment on flavor, texture, and general acceptability. All of those who tried the fish rated it good, with a neutral or bland flavor. None considered it excessively soft.

Texture

The poor texture of hake has been associated with a microscopic myxosporidian parasite (Kudoa sp.) in the muscle tissue, similar to parasites reported in other fish species (Willis, 1949; Fletcher, Hodgkiss, and Shewan, 1951; and Patashnik and Groninger, 1964). The muscle portions of hake that are heavily infected with the parasite appeared to have serious proteolysis of the tissue with accompanying liquefaction and mushiness (Willis, 1949). When the fish are caught, the flesh may appear normal in all respects. But about six to eight hours after the fish are caught, spores can be found in all stages of maturity; and twelve to fourteen hours later, the spores will have increased enough to cause the milky or liquefied condition. It is hypothesized that the postmortem breakdown of the musculature is caused by a powerful extracellular proteolytic enzyme released by the parasite, rather than by bacterial activity (Willis, 1949). Presumably, the enzyme is removed by blood circulation while the fish are alive; but after the fish dies, the enzyme accumulates and progressively diffuses outward from the infected focus to the noninfected areas.

One hypothesis is that the incidence of the parasite might be related to the abundance of hake. Therefore, it was felt that the harvest of large proportions of the hake

resource by the foreign fishing fleet over the last 10 years might have reduced the incidence of the parasite. However, examination of samples collected during the summer of 1976, indicated an incidence of the myxosporidian parasite approximately equal to that found by studies conducted prior to the onset of the foreign fishery. Previously published reports indicated a 20 to 30 percent incidence of the parasite in hake (Dassow, Patashnik, and Koury, 1970).

Potential Markets

A number of institutions, fish processors, and fish brokers were contacted and offered samples of hake fillets for their consideration. Los Angeles School System personnel have had experience with precooked fish sticks. Although they had tried other species, they definitely preferred cod. Based on experience with fish sticks made from pollock, they would not consider using deboned fish for the manufacture of fish sticks. They have not indicated an interest in receiving future supplies of hake.

The Community Redevelopment Agency of Los Angeles was provided samples of hake but has not indicated any interest.

Several secondary processing companies that manufacture fish sticks and portions were contacted. One company was very interested in frozen hake fillet blocks which could be cut into fish sticks or portions and precooked, but they

had no interest in deboned fish because their customers had previously rejected products made from that product. The primary concern was a sufficient and sustained supply and a suitable price to make hake competitive with other species of fish they were using.

Fish brokers in the Los Angeles area were contacted to determine their interest in hake. Most brokers considered hake inferior to products made from species they were distributing. They would only consider distributing hake if the price was well below that of other accepted species. None of the brokers reported that they had sold any hake or hake products, regardless of the country of origin.

DISCUSSION

Resource Availability

The larger estimates of maximum sustained yield of Pacific hake, made in the late 1960's and early 1970's, were about 200,000 t. (220,000 tons). However, these estimates were made when two unusually strong year classes, 1961 and 1962, were still present in the population (Dark, 1976). More recent population estimates indicate that the estimated maximum sustained yield has declined to about 150,000 t. (165,000 tons) (Dark and Nelson, 1977). There is other evidence, including a decline in the age and size composition of the fish landed and a shift southward of the

center of fishing effort, that the resource may have been overfished. The foreign fishery, which originally was dependent mostly on 4-year and older fish, has become increasingly dependent on immature 2- and 3-year fish. Also, the foreign fishing effort, which was previously concentrated off Oregon, Washington, and British Columbia where the larger, older fish could be found, had become centered off northern California by 1976. Additional information about the relative abundance and distribution of juvenile hake supports the hypothesis that there has been a general decline in the hake population (Dark and Nelson, 1977).

Although hake may have been overfished by recent foreign fishing efforts, it still represents a very large, available resource. Legislation to establish and enforce a 200-mile economic zone became effective 1 March 1977. This legislation provides the basis for the management of fisheries such as that for hake, including regulation of foreign fishing efforts, and would allow for the development of a domestic fishery. If the domestic fishermen can demonstrate the ability to catch and sell a portion of the resource now being caught by a foreign fishery, the share of the catch allocated to the foreign fishery can be proportionately reduced. The size of the annual harvest, if 150,000 t. (165,000 tons) is accepted as a realistic estimate of the

maximum sustained yield, would be substantial. In comparison, the trawl landings of all species of ground fish (generally sole and rockfish) by the United States and Canada has totaled less than 90,000 t. (99,000 tons) per year in recent years (Verhoeven, 1977).

It is clearly evident that the resource necessary to support a Pacific hake fishery is available. Further studies designed to more precisely define the size and distribution of the resource would be necessary as the fishery developed. However, existing knowledge is sufficient to support the development of a fishery.

Fishing Methods

U.S. fishermen have caught Pacific hake for many years using standard bottom trawl equipment. It is conceivable that continued use of this equipment would enable domestic fishermen to catch enough fish to sustain a developing hake fishery. However, more sophisticated techniques using electronic detection equipment and midwater trawls are well-known from observations of the foreign fishing fleets and from studies conducted by the National Marine Fisheries Service (Bureau of Commercial Fisheries, 1970). As the capital becomes available for vessel modifications and fishing gear improvements, it is reasonable to expect that the domestic fishing fleet can be modified to catch Pacific hake

as efficiently as anyone. Additional research concerning hake distribution and behavior, and various new types of fishing gear and electronics, would further assist the development of the domestic fishing capability. Since the fishery for hake will apparently be seasonal, consideration should be given to the opportunities for employment of hake fishermen and their gear during the period November through March.

Processing

Rapid handling of hake is essential to maintain desired flesh texture and quality during storage. The fish should be iced or placed in refrigerated brine tanks as soon as they are brought aboard the fishing vessel. Any processing, whether it is filleting, deboning, or simply heading and gutting, should be accomplished so that the fish can be frozen three to four hours after the fish are landed at the plant. If the fish are filleted, a plate freezer should be used for rapid freezing. All product forms should be stored at a temperature of at least -18° C (0° F). The -18° C (0° F) storage should be maintained during transportation of the product, and, in particular, significant temperature fluctuations should be avoided. Inventory records should be kept so that the products which were first processed can be first shipped. Packaging should be designed, to the

extent that economics permit, to provide as much protection from oxidation as practicable in order to extend the shelf-life.

Marketing

Since hake has not been marketed domestically in any volume, it represents a new product. However, similar fish such as Alaskan pollock and Atlantic whiting are presently sold in the marketplace, and products from these fish are found in the market in various forms, including headed and gutted whole fish, fillets, and frozen fillet blocks. The marketing of Pacific hake should follow the same pattern and compete directly with these fish. Although this study indicated that filleted hake was preferred to deboned hake, the latter should not be ignored. Particularly, the foreign market may be interested in deboned hake.

One potential market for hake is in the processing of fish sticks and fish portions. These products are made from frozen fillet blocks or deboned fish flesh formed into blocks. The raw material is cut into various shapes, breaded, and sometimes precooked prior to reaching the retail market. Production of fish sticks has nearly doubled from 29,500 t. (32,500 tons) in 1960 to 57,660 t. (63,500 tons) in 1973. The growth in fish portions has been even more rapid, rising from 22,250 t. (24,500 tons) in 1960 to 134,380 t. (148,000

tons) in 1973. Fish sticks production has grown at an average rate of 5.3 percent per year. Production of fish portions has grown by 14.7 percent per year. Combined production of the two has risen at the rate of 10.6 percent per year. The lower estimate of production for sticks and portions assumes that total production will continue to grow by 10,760 t. (11,850 tons) per year, the average annual increase since 1960. At this rate, production would reach 317,800 t. (350,000 tons) by 1985 (National Marine Fisheries Service, 1976a).

Fish consumption in the U.S. has continued to rise, but over 50 percent of the fish consumed in the U.S. are provided by imports (mostly the more commonly used fish such as cod, tuna, and halibut) (National Marine Fisheries Service 1976b, 1976c, and 1976d). The new fishing limits should increase demand for these fish and raise their prices, leaving the door open to the introduction of fish presently not being used. Hake has the qualifications needed to fit into this market. In particular, the bright picture for the future market for fish sticks and portions provides an opportunity for the hake fishing industry to supply some of this demand. If events continue as they have in the past, U.S. landings will continue to show no increase. The domestic supply of traditional species of fish used in the manufacture of sticks and portions has either decreased or

remained level, thus the industry would have to continue to rely on imports of fish blocks to meet the growing demand. The price of cod blocks has continued to rise, forcing manufacturers to pass this increase on to the consumer, where it has met resistance. The solution seems to be a moderately priced, non-traditional species as a substitute.

The Japanese have fished for pollock off the Atlantic and Pacific coasts of the United States for the past ten years. Fish consumption in Japan was 12.5 k (27.5 lbs.) per capita in 1970. The projected demand by 1980 is 12.85 k (28.3 lbs.) or an increase of 888,000 t. (978,000 tons). One of the principal fish products made and eaten by the Japanese is kamaboko, a fish cake made from various species. This product is formed from minced fish flesh, ground, seasoned, and battered. It is either steamed or deep-fried. In 1968, about 25 percent of the Japanese catch was processed into kamaboko products (Okada, Miyauchi, and Kudo, 1973). The use of hake for this market has great potential. Recently, a group of Japanese visited our area to inquire about the availability of hake or similar fish which they were considering for the minced flesh product. Capturing a small percentage of Japan's projected market growth for kamaboko would amount to a substantial sales volume.

Economics

Since hake falls into the category of a new product, the producer will be faced with setting the price for the first time. The prices of other species of fish that would likely be in direct competition with the introduction of hake into the marketing system were examined. During the last eleven months of 1976, the average price for frozen Alaskan pollock and whiting fillet blocks was 42 cents per pound. If hake products can profitably be offered for sale at or below this level, they should meet with acceptance in the marketplace.

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